

Metamaterial Science and Technology Grand Challenge LDRD



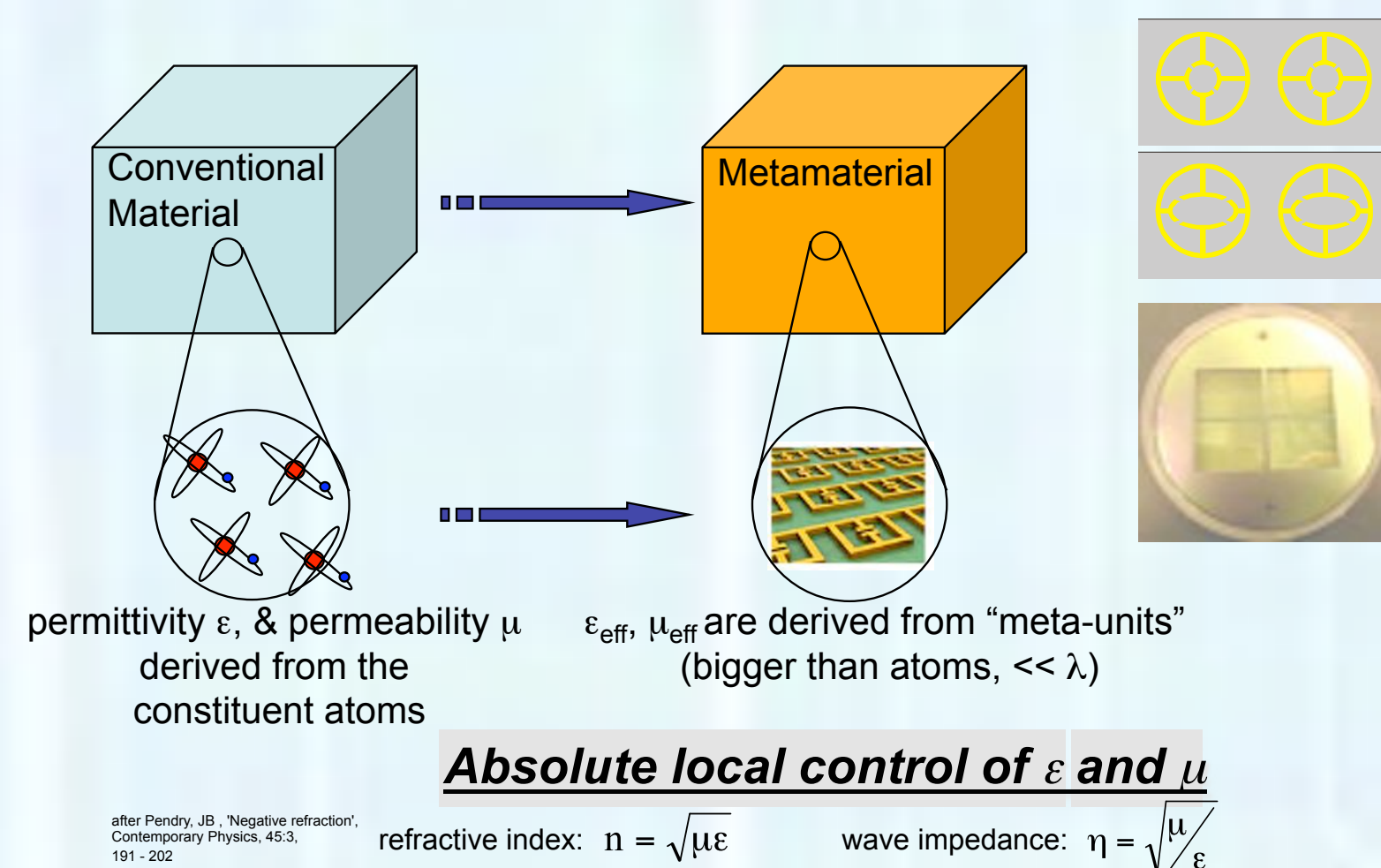
Sandia National Laboratories

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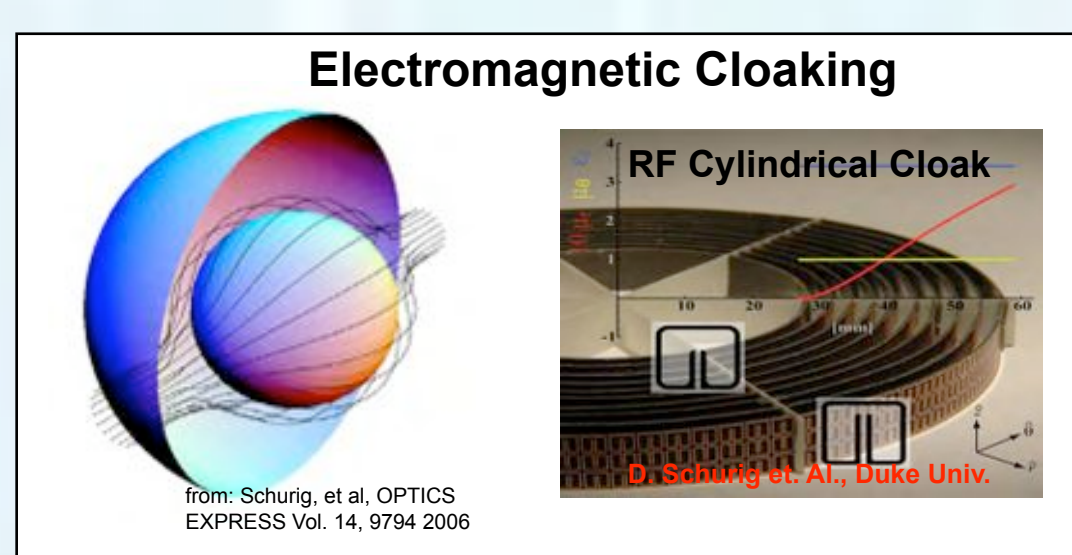
Problem

Background

What is a metamaterial? $\mu\epsilon\alpha = \text{meta} = \text{"beyond"}$

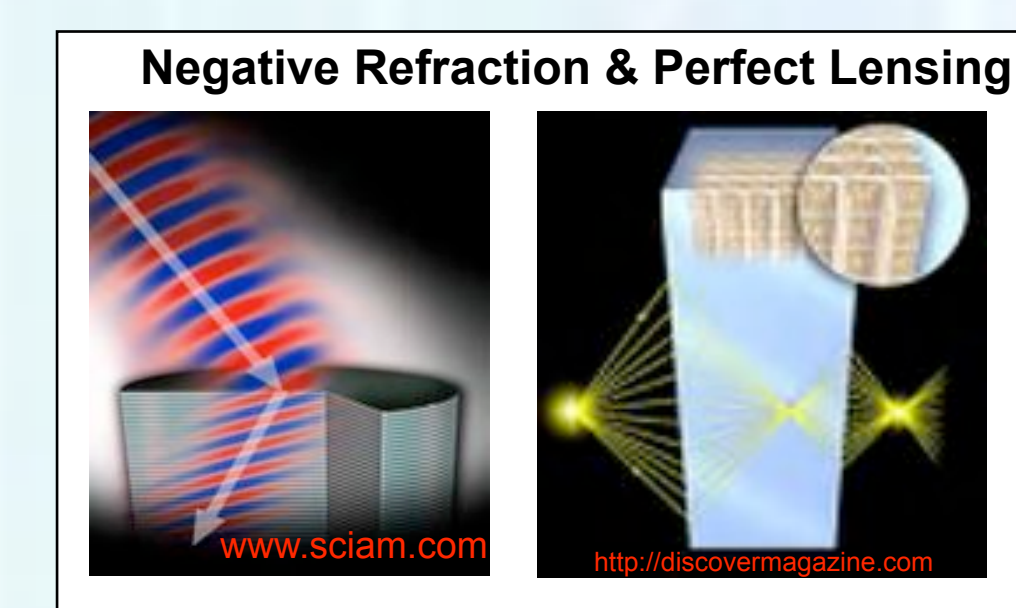


Metamaterials: Why all the hype?



- cloaking
- negative index materials
- perfect lens
- active optical devices
- nonlinear components
- concentrators
- perfect absorbers
- photon funnels

- Many theoretical predictions of astonishing devices
- Exploit the freedom of ϵ and μ afforded by meta-materials
- Rigorous solutions to Maxwell's Equations



Metamaterials "Hype Gap"

Rapid progress at optical frequencies, but still a large gap between theory and demonstrated optical devices.

- RF devices are appearing:
 - Netgear wireless
 - rayspan.com & sensormetrix.com
- Practical IR and visible devices nowhere in sight
 - Fabrication is difficult, but not fundamentally limiting
 - real applications may require large areas \Rightarrow scalable approaches
 - Most current approaches are narrowband
 - Optical loss limits performance: (ohmic losses of metallic structures)
 - Path to broadband will likely require loss trades

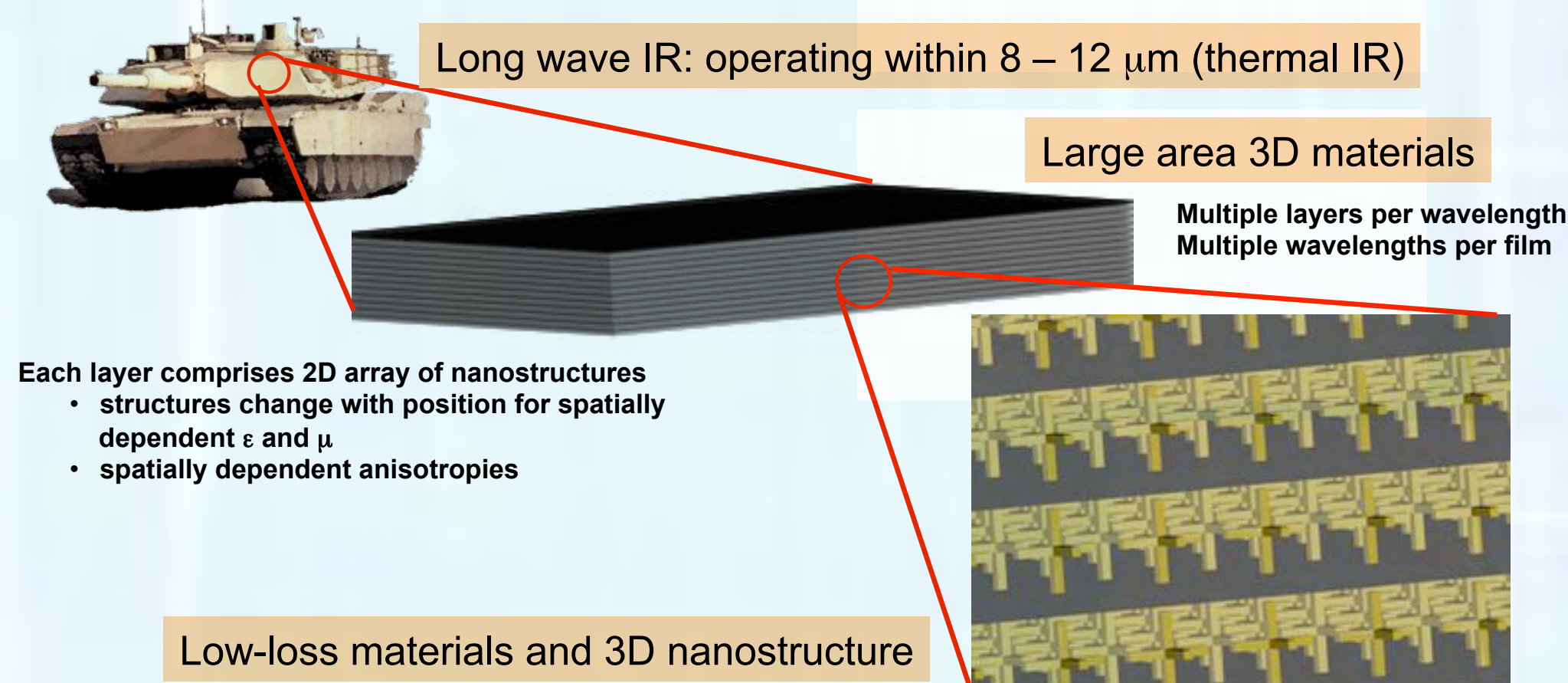
"NETGEAR's new Wireless-N products, which are based upon the IEEE 802.11n Draft 2.0 specification and have all been certified by the Wi-Fi Alliance, incorporate multiple internal antenna arrays based on revolutionary metamaterials technology..."

<http://www.netgear.com/About/PressReleases/en-US/2008/20080106b.aspx>

Loss is the key limitation for many optical applications

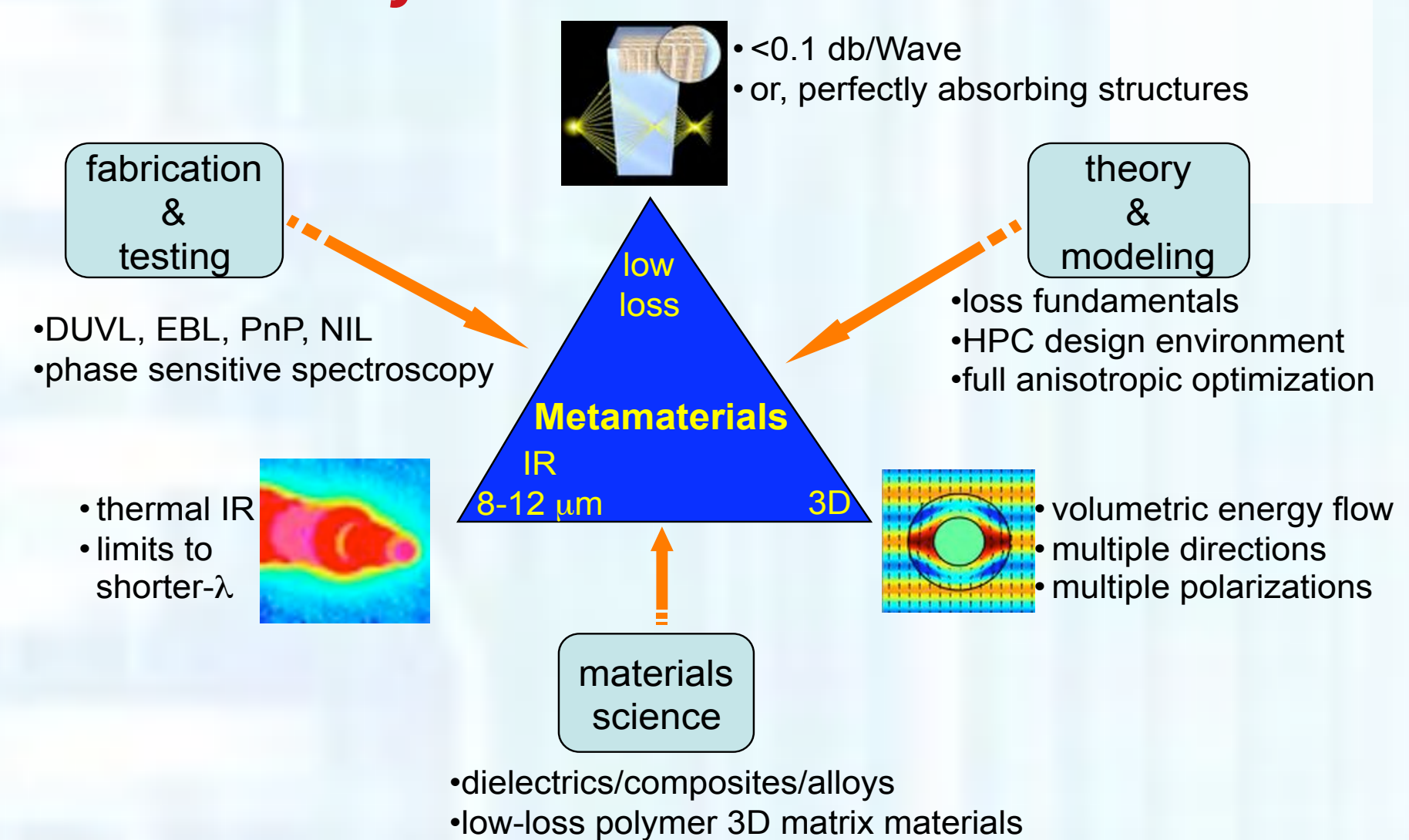
Grand Challenge Vision & Goal: Useful 3-D IR Metamaterials

- Useful, low-loss, 3D, LWIR metamaterials
- Capability to custom-engineer absorption or loss
- Novel constituent materials and designs for low loss ($0.1\text{dB}/\lambda$)
 - 100x more transparent than best current IR metamaterials
- End Goal: Science and infrastructure for new materials



Approach

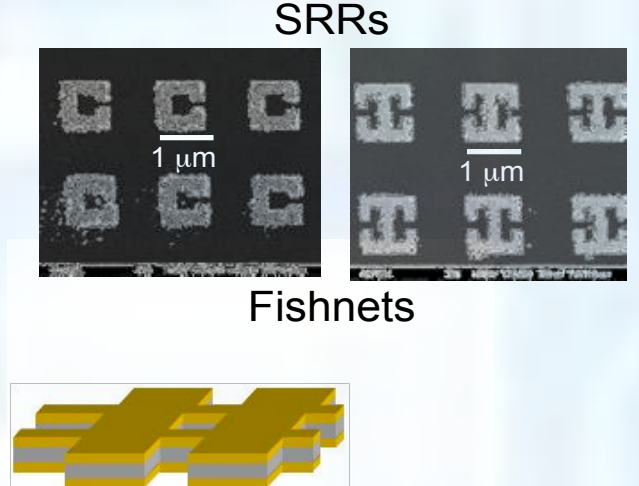
Metamaterials Science & Technology: Approach & Project Structure



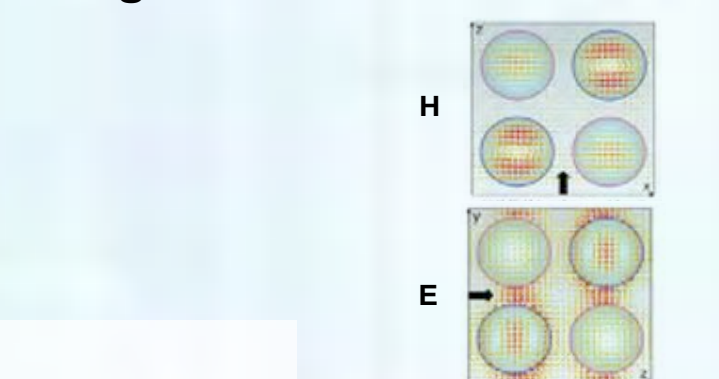
Results

Selected Metamaterial Accomplishments: Theory, Materials, Fabrication, Characterization

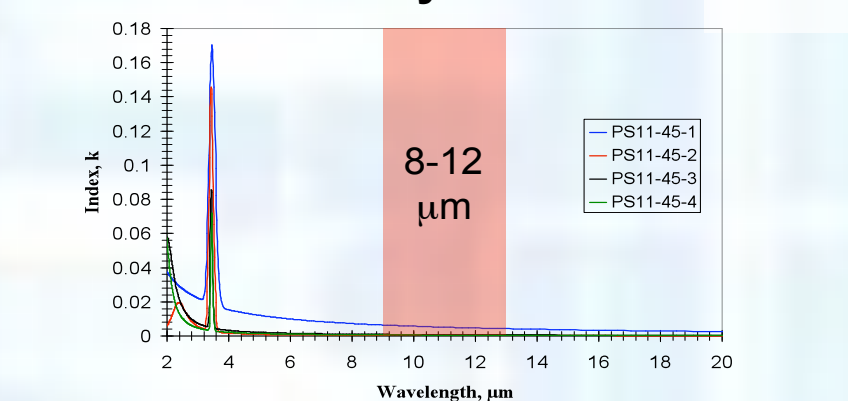
Jumpstart Metamaterials



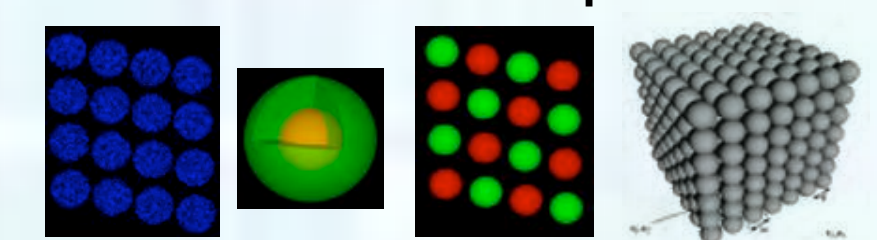
Isotropic, Low-loss Negative Index Metamaterial



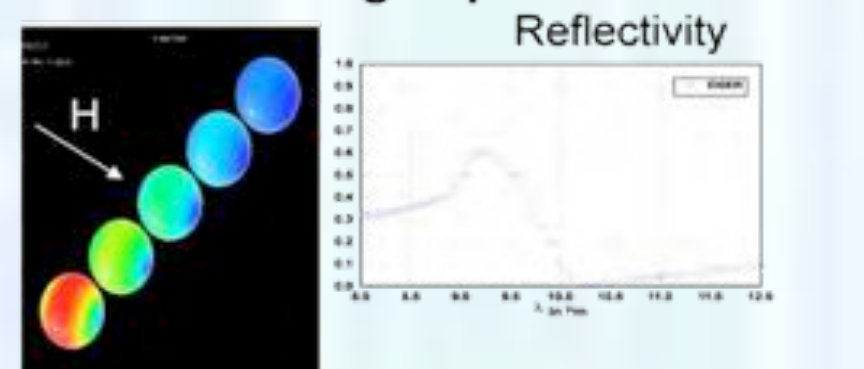
Low IR Loss Polymers & Ceramics



Effective Medium Multipole Models



HPC modeling of perfect absorber



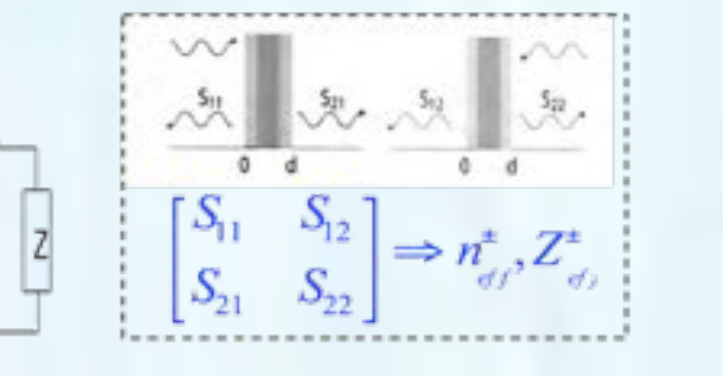
2D Silicon Carbide Metamaterial



Detailed & Accurate Circuit Models



Parameter Retrieval Codes



- also ...
- New 3D fabrication process in development
- Phase sensitive spectrometers developed
- Dielectric resonator metamaterial analysis
- Polaritonic metamaterial analysis

Significance

- A Truly Grand Challenge Problem: Hard Science, Many Applications
- Demonstrate a low-loss 3D IR metamaterial, ready for applications.
- Establish differentiating metamaterial capabilities at Sandia (design/simulation, materials, fabrication/characterization) to ensure follow-on programs.
- Provide fundamental contributions to the science of metamaterials.
- Metamaterial GC team has been successfully integrated and is producing high-quality results, publications, and presentations.
- Sandia is now recognized as a significant player in the metamaterial arena.

